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EFFECTIVENESS OF PLANT EXTRACTS FOR THE CONTROL OF RED MITE (RAOIELLA INDICA HIRTS) IN THE COCONUT TREE (COCOS NUCÍFERA L.)

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Abstract: Worldwide, the cultivation of Cocos nucifera is cultivated in 92 countries, Mexico occupies ninth place, with the state of Guerrero being the first place nationally. However, its economic production is affected by pests and diseases, one of them is *Raoiella indica*, its only means of control being chemical insecticides that contribute to the environmental crisis. In this work, the concentration-lethality of 3 biological and two chemical extracts on *R. indica* was compared, as well as the LC_{50} for each of the products. These products were applied by spraying, using the Burgerjon tower, directly on adult females of *R. indica*, placed on leaflet discs 5 cm in diameter. Mortality was recorded at 24, 48 and 72 hours. At all these times, Abamectin showed the lowest LC_{50} values, which means the highest toxicity; In decreasing order of toxicity, Asphix, Saf-T-Side, Spiridiclofen and Biodie followed. The LC_{50} of Neem Higuer, Neem Canela and Bio-Piretrin were not estimated because in the preliminary bioassays it was observed that they have minimal toxicity. The use of Asphix is preferably recommended for the control of *R. indica*, due to its low price compared to Abamectin, as well as its status as a biorational product.

Keywords: biological, mortality, CL_{50}, concentration, mite.

INTRODUCTION

In Mexico, one of the most economically important pests that affects the coconut crop (Cocos nucifera L.) and recently in the state of Guerrero, is the red palm mite (*Raoiella indica Hirst*). This mite was recorded for the first time in India in 1924; It was distributed in large areas around the Indian Ocean, limited to the west in Egypt and Israel (Jeppson et al., 1975). However, in 2004 it was detected in Martinique (Flechtmann and Etienne, 2004), from where it dispersed throughout the Caribbean islands (Kane et al., 2012). In

2008 it invaded Venezuela, Florida and Cuba (Vásquez et al., 2008; Peña et al., 2008; De La Torre, 2010), and in 2009 it arrived in Mexico, where it was detected on Isla Mujeres.

Currently the red mite has spread in the states of Campeche, Baja California Sur, Colima, Chiapas, Guerrero, Jalisco, Michoacán, Nayarit, Oaxaca, Sinaloa, Sonora, Tabasco, Quintana Roo, Veracruz and Yucatán, where it affects a total of 172 municipalities (SENASICA, 2016). Its main hosts are C. nucifera, Areca catechu L., Phoenix dactylifera L., Heliconia sp., although it can infest various species of the families Arecaceae, Musaceae, Heliconiaceae, Zingiberaceae, Strelitziaceae and Pandanaceae (Welbourn, 2007; Vásquez, 2008 ; Carrillo, et al., 2011). In Mexico, its hosts with the greatest economic value are the coconut tree and the banana (SENASICA, 2014).

It has been confirmed that coconut cultivation is a very susceptible food source towards *R. indica* (Ramos and Moreno, 2014). The effects of this mite in nurseries cause the death of plants, while in established plantations it begins to damage mature leaves, causing chlorosis and finally necrosis, as well as the abortion of flowers (Rodríguez et al., 2007; Navia 2008; Carrillo et al., 2011). The control of this pest in Mexico so far is only chemical using products such as Abamectin, Spiridiclofen and sulfur, but the use of these and other chemical products tends to trigger a large number of environmental imbalances and resistance to them (SENASICA, 2014).

In this study, comparisons of mortality of the red palm mite were made with different commercial plant extracts, the most used chemical product and the control (water). It is worth mentioning that this would be the first work reported for the control of *R.indica* using commercial plant extracts.

MATERIALS AND METHODS

The study was carried out in the Toxicology and Acarology laboratory of the Postgraduate Program in Phytosanitary, Entomology and Acarology, Montecillo Campus, of the Postgraduate College, located at Km. 36.5 Carr. México-Texcoco, Montecillo, State of Mexico. As a source of the mites used in the bioassays, infested coconut palm seedlings from Tecpan de Galeana, Guerrero were used.

Concentration-lethality bioassays were carried out on young adult females, between one and four days of age. To obtain females of this age range, coconut palm leaflets highly infested by this mite were taken; All males and females were manually eliminated, those recognized by their larger size and the presence of spots on the opisthosoma.

Only formed pairs were left (male after the female), because that is where the female is in the second nymphal or deutonymph stage; That is, she is in a stage of quiescence close to molting to become an adult; Normally a male fixes behind her to copulate with her as soon as she detaches from her nymphal exuvia (Flores-Galano et al., 2010). These leaflets were allowed to rest for 3-4 days at room temperature in the city of Texcoco. They were checked daily in order to be able to separate the females that had emerged and whose age was known with precision of ±1 day.

The mortality of *R. indica* caused by six plant extracts was evaluated: Neem Higuer, Neem Canela, Bio-Piretrin, Biodie, Saf-T-Side and Asphix 90 (Promotora Técnica Industrial 2009; Agrícola Innovación 2017; Ultraquimia Agricolas 2017) (Bionutra, 2017) and two chemical products, Abamectin and Spiridiclofen, currently used to control the mite.

BIOASSAYS IN YOUNG FEMALES

Once there were enough young adult females of the red palm mite, the experimental units were prepared for the application of the chemicals to be evaluated. To do this, 5 cm diameter discs were cut from coconut palm leaflets with the help of a punch, these were placed in Petri dishes and their edges were covered with wet cotton in order to keep them fresh for longer. 10 young females were transferred to each Petri dish (experimental unit) using a 0000 brush; Each chemical was applied at five to six concentrations, each with four replicates; The application was carried out by spraying using the Burgerjon (1956) spray tower, 0.0012±0.67. Mortality was evaluated at 24, 48 and 72 hours.

PRELIMINARY BIOASSAYS

Preliminary bioassays were carried out in order to obtain the biological response window. This is defined as the interval between the highest concentration of a product that does not kill any of the treated specimens (or that does not cause mortality significantly different from that of the control), and the lowest concentration of the same product that causes 100% of mortality.

To do this, each product was started at the original concentration of the commercial product, of which dilutions were made 1:10, 1:100, 1:1000 and more towards both ends, when necessary.

FINE BIOASSAYS

Once the biological response window was estimated, the products were applied at increasing concentrations, separated logarithmically, within the interval established by said window, to estimate the mean lethal concentrations. The application was also by spraying, with the method and quantities applied as described above. The concentrations expressed in ml/L used for each of the treatments were: Saf-T-Side, 0, 0.5, 1.6, 5, 15.8; Asphix, 0, 0.02, 0.07, 0.28, 1.17; Abamectin, 0, 0.004, 0.009, 0.02, 0.043, 0.093; Spiridiclofen, 0, 1.11, 2.05, 3.79, 7.02, 12.98; and Biodie, 0, 2.8, 6.5, 15.2, 35.4 82.4.

Mortality values, expressed as the number of dead individuals over the total number of treated individuals (10), with readings at 24, 48 and 72 h, were analyzed by simple linear regression using the Excel program (Microsoft). Likewise, the coefficient of determination (r2) was determined, which allowed us to know the goodness of fit to the model. Once the regression equation was determined, the mean lethal concentrations were estimated by interpolation.

RESULTS

PRELIMINARY BIOASSAYS

The concentrations that resulted in 0 and 100% mortalities were the following: Saf-T-Side, 0.05 ml/L and 50 ml/L; Asphix, 0.001 ml/L and 4.8 ml/L; Abamectin, 0.002 ml/L and 0.2 ml/L; Spiridiclofen, 0.6 ml/L and 24 ml/L; Biodie, 1.2 ml/L and 192 ml/L. From them, those used in the fine bioassays were estimated.

Only preliminary tests were carried out with the extracts Neem Higuer, Neem Canela and Bio-Piretrin since they had a very low toxicity for *R. indica*, the amount of product used was greater than that of water, so they were discarded for the tests. fine.

FINE CONCENTRATION-LETHALITY BIOASSAYS 24 HOURS

Figure 1 shows that for most products, mortality increases as the concentration increases. In the case of Abamectin, the linear behavior is clearly noted, this product being the most efficient compared to organic products. It is worth mentioning that Spiridiclofen, despite being a synthetic chemical product, behaves differently, since it increases the concentration and does not necessarily increase mortality. The linear regression model does not explain this behavior, because it cannot predict what is expected, as it presents low mortality at high concentrations. It is also noted that organic products surpass Spiridiclofen in mortality percentage. Likewise, it can be seen that mortality is linear over concentrations and not over time. On the other hand, it is worth mentioning that at high concentrations organic products caused greater mortality than Spiridiclofen and at low concentrations it resulted in higher mortality.

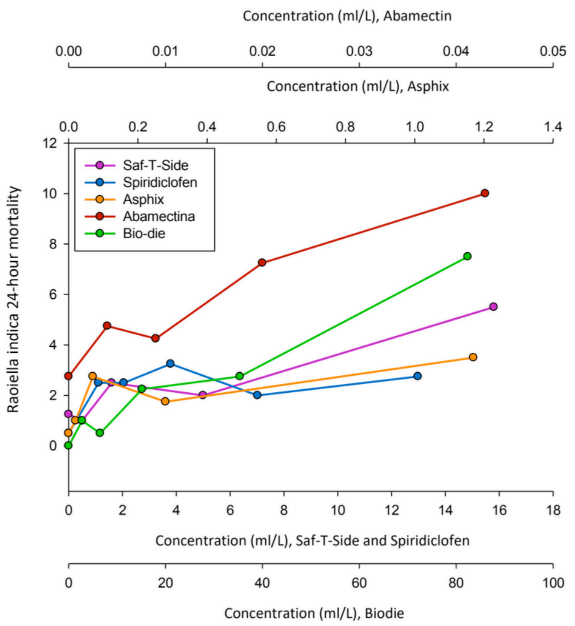

Figure 1. Concentration-lethality at 24 hours of products applied on R.indica.

CONCENTRATION-LETHALITY 48 HOURS

Figure 2 similarly shows that for most products, mortality increases as the concentration increases. Abamectin clearly follows linear behavior, being the most efficient product. While Spiridiclofen does not follow this pattern, since it increases the concentration and does not necessarily increase mortality. Also note that the organic products Saf-T-Side, BIOdie and Asphix surpass Spiridiclofen again.

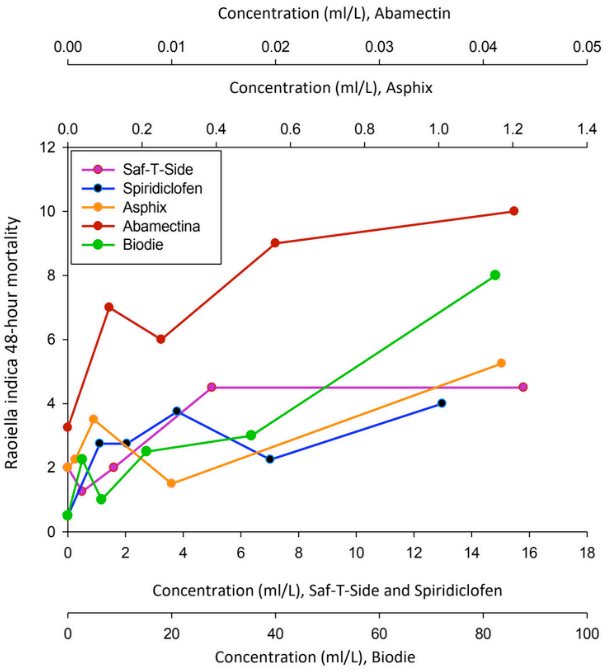

Figure 2. Concentration-lethality at 48 hours of products applied on R. indica.

CONCENTRATION-LETHALITY 72 HOURS

Figure 3 shows that mortality does not depend on the time of exposure to the product, but rather on the increase in concentration. In this figure it is noted again that Spiridiclofen is less efficient than even organic products, since, although the concentration increases, mortality decreases, but this is not the case with the rest of the products, which increase the concentration and increase mortality. On the other hand, Abamectin also clearly follows linear behavior, being the most efficient product.

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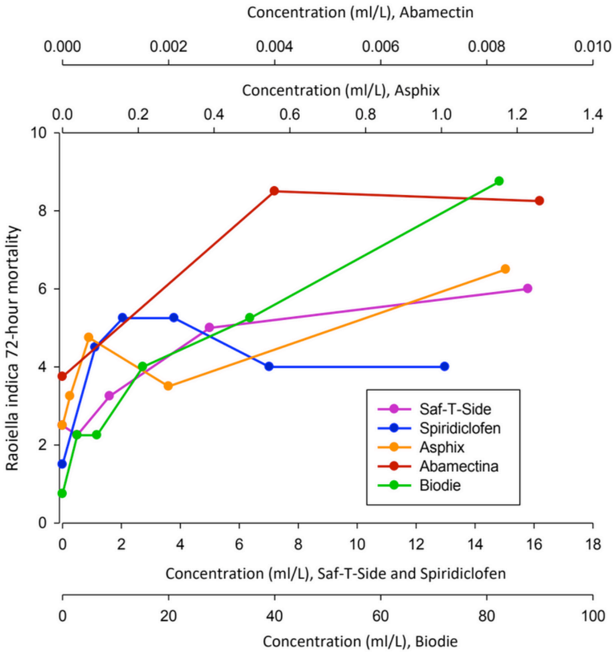

Figure 3. Concentration-lethality at 48 hours of products applied on R. indica.

MEDIAN LETHAL CONCENTRATION: CL_{50}

It is observed that the linear regression models, adjusted to each mortality response with each treatment, explain the variability of the data (See tables 1, 2 and 3).

In the tables there is R2 that verifies the goodness of fit of the regression models as it is greater than 0.6 except, for Spiridiclofen, which in the three exposure times has a very low R2 (maximum 0.24).

On the other hand, it is noted that Abamectin is the one that needs the lowest concentration of product to kill 50 percent of the population and that Spiridiclofen needs a higher concentration than Saf-T-Side and Asphix.

CL_{50} 24 hours			
Products	Regression equation	R^2	$x = CL_{50}$ (mL/L)
SAF-T-SIDE	y = 0.2625x + 1.2479	0.911	**14.2991616**
ASPHIX	y = 1.9131x + 1.3108	0.5893	**1.92848928**
ABAMECTINA	y = 160.77x + 3.3562	0.9456	**0.01022454**
SPIRIDICLOFEN	y = 0.08x + 1.8909	0.1655	**38.86375**
BIO-DIE	y = 0.0856x + 0.3041	0.9677	**54.8586449**

Table 1. Lethal LC_{50} concentration obtained in 24 hours.

R^2= Determination coefficient.

CL_{50} 48 hours			
Products	Regression equation	R^2	$x = CL_{50}$ (ml/L)
SAF-T-SIDE	y = 0.1864x + 1.9965	0.911	**16.1131974**
ASPHIX	y = 2.4395x + 2.1486	0.6415	**1.16884608**
ABAMECTINA	y = 131.17x + 5.0562	0.7304	**-0.00042845**
SPIRIDICLOFEN	y = 0.0766x + 2.687	0.2463	**30.1958225**
BIO-DIE	y = 0.0823x + 0.9246	0.931	**49.5188335**

Table 2. Lethal concentration LC_{50} obtained in 48 hours.

R^2= Determination coefficient.

CL_{50} 72 hours			
Products	Regression equation	R^2	$X=CL_{50}$ (mL/L)
SAF-T-SIDE	y = 0.2266x + 2.7621	0.8301	**9.87599294**
ASPHIX	y = 2.7277x + 3.2599	0.7409	**0.63793672**
ABAMECTINA	y = 477.46x + 4.7643	0.6487	**0.00049365**
SPIRIDICLOFEN	y = 0.0481x + 3.8671	0.0282	**23.5530146**
BIO-DIE	y = 0.0883x + 1.7807	0.9482	**36.4586636**

Table 3. Lethal concentration LC_{50} obtained in 72 hours.

R^2= Determination coefficient.

DISCUSSION

The LC_{50} obtained from Abamectin was the lowest, so this product was the most toxic in this work (Table 1 and 2). This result is similar to the data recorded by Sánchez-Vázquez et al. (2017), who estimated the LC_{50} of 0.0001, 0.0003, 0.0011 ml/L of Abamectin on *R. indica* at 24 h, and Cerna et al. (2009), who found that the LC_{50} obtained for abamectin on Tetranychus urticae was 0.0018 ml/L. It must be noted that Sánchez-Vázquez et al. (2017) report that the most toxic acaricides for *R. indica* adults were fenazaquin and milbemectin.

On the other hand, according to Carrillo et al. (2011), Abamectin caused a mortality greater than 50% on the mite T. urticae at a dose of 10% and 20%; However, the units used are not equal to the LC_{50} obtained in the present work, so the comparison can be considered tentative. The next most toxic product was the Asphix biological extract, with an LC_{50} of 1.9284 ml/L (Table 1). It is worth mentioning that this pesticide has a market cost of $126.00/L, so it can be a biorational and low-cost alternative that can be taken into account for the control of the *R. indica* mite.

Asphix extract is composed of soybean vegetable oil, which has been proven effective against stored grain pests. Cerna et al. (2010) tested concentrations of 2000, 5000 and 10000 ppm and 50% mortality was observed in the corn weevil Sitophilus zeamais, although in this case the lethal concentration (LC_{50}) was not evaluated, but it can be compared since mortality was also greater than 50%.

On the other hand, the chemical product Spirodiclofen presented one of the highest LC_{50}, with 38.8637 ml/L (Table 1) and could develop resistance by the red mite. Montoya et al. (2017) tested this chemical product on adult females of T. urticae and found that it has slow effectiveness, while Marcic et al. (2009) point out that mortality is lower within the first 48 hours.

At 48 hours, Abamectin presented an LC_{50} of -0.0004 (Table 2), the negative value can be explained because in the control there was a high mortality, which could be attributed to the handling of the specimens. The LC_{50} value at 48 hours is therefore questionable. At 72 hours, likewise, the most toxic concentration recorded was for Abamectin, with an LC_{50} of 0.004 ml/L, followed by that of the Asphix extract, Saf-T-Side, Spirodiclofen and Biodie (Table 3).

Abamectin has a cost of $600.00/L, so it is not viable for the producer, in addition to the fact that the mites have a high reproduction rate and short survival, which accelerates the resistance process (Whalon et al., 2008; Van-Leeuwen et al., 2010). According to Campos et al. (1995) and Cerna et al. (2005), Abamectin presents a high level of resistance by the mite T. urticae; This may be because these organisms have defense characteristics such as detoxifying enzymes (Benbrook, 1986). The biological extract Asphix 90, which was next in toxicity, has a cost of $126.00/L, so it can be a biorational alternative that can be taken into account for the control of the *R. indica* mite.

On the other hand, products based on neem and Neem Pro, Organic Neem and Natuneem have been tested in strawberry cultivation and the average lethal concentration LC_{50} of 0.0003, 0.0007, 0.0011 ml/L, respectively, has been obtained. with 95% confidence intervals against the mite T. urticae. Its importance lies in the fact that it does not cause negative effects on its predator, which is why it can be considered for integrated pest management in a crop (Soto et al., 2011).

Finally, it must be noted that products based on neem (*A. indica*) were evaluated; These are Fig Neem and Cinnamon Neem, which have repellent and/or anti-feedant properties (Schmutterer, 1990). However, because the mites treated with these products were confined to observation areas, they could not escape, therefore, their repellent effect was not evaluated in this work. Its possible antifeeding effect could be tested in readings at longer times, since it has been shown that the red mite tolerates more than 10 days without feeding (Ramírez, 2014).

Due to the above, they must not be ruled out as possible alternatives for the control of the red mite, but it is suggested that other studies be carried out to evaluate their effect, since the acaricidal effect of neem on *R. indica* has been proven with a 90% mortality rate. in 72 hours (Ruiz-Jimenez et al., 2021), in T. urticae, with 83.9 and 85.2% mortality (Castiglioni et al., 2002) and on Schizotetranychus. hindustanicus with a mortality of 96.4% in 72 hours (Ortiz-Meneses et al., 2022). Ruiz-Jimenez et al., (2021) mention that the possible development of resistance to pests is minimal, due to the variability in the modes of action of the compounds in the neem extract, so its use is viable due to its compounds. natural, in addition to not affecting the ecosystem (Ortiz-Meneses et al., 2022).

CONCLUSIONS

Of the products tested, the chemical Abamectin was found to be the most toxic product with the lowest concentration; Therefore, it was the product that caused the highest mortality, but if it continues to be used intensively in the not too distant future, the *R. indica* mite can generate resistance, in addition to the fact that the mites have a high reproduction rate and short survival. which speeds up its process. The biological extract Asphix 90 followed in terms of toxicity and can be a biorational alternative for the control of *R. indica* in coconut cultivation, in addition to being a much more economical product with a price of $126/L compared to Abamectin which is $600/L.

It must be noted that Spirodiclofen had one of the highest LC_{50}, so it is not recommended to continue using it, since in addition to being a chemical product with the potential to contaminate the environment, the red mite can develop resistance; on the contrary, they result Even Asphix and Saf-T-Side are more effective.

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